Full Vehicle Simulation for Series Hybrid Vehicles

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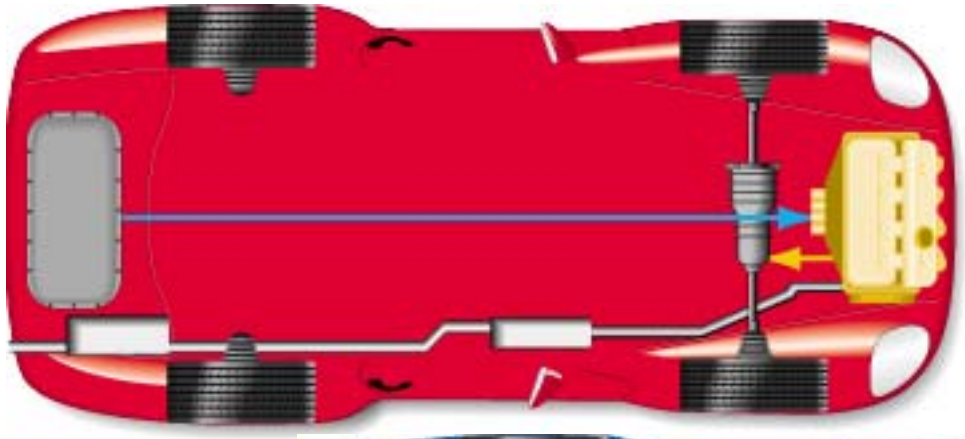
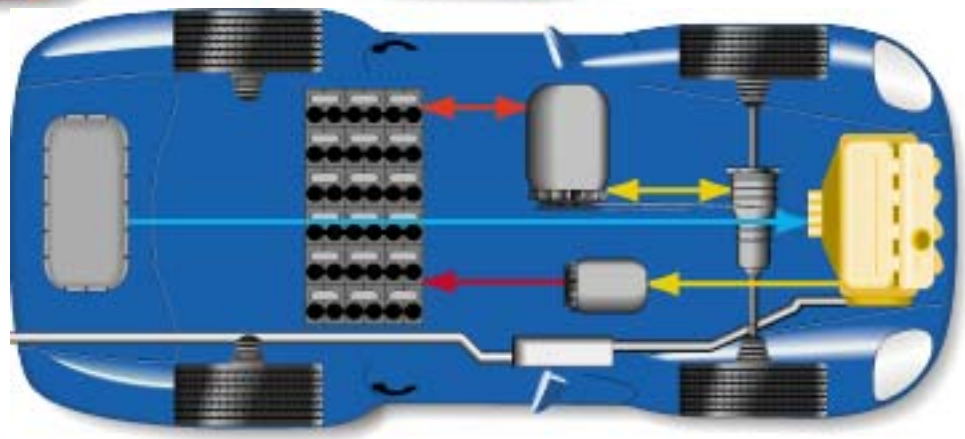
SAE

DELPHI

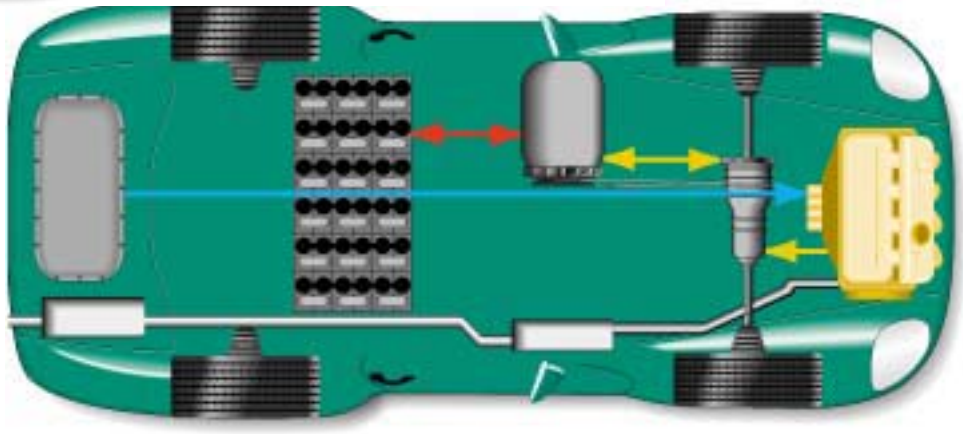
ADVISOR Vehicle Templates



Traditional Vehicles



Series Hybrid Vehicles



Parallel Hybrid Vehicles

Original Style ADVISOR

Goal: Predict Vehicle Fuel Economy over Drive Cycles

All modeling is in Simulink

All electrical modeling is based upon power flow, not circuit equations

Classes of Vehicles

- Traditional vehicles
- Series hybrid vehicles
- Parallel hybrid vehicles

Co-Simulation Style ADVISOR

Goal: Predict Vehicle Fuel Economy over Drive Cycles

All propulsion modeling is in Simulink

All electrical modeling is in Saber

Classes of Vehicles

- Traditional vehicles
- Series hybrid vehicles

This paper focuses solely on the series hybrid vehicle simulations with co-simulation

Series Hybrid Simulation Strategy

Goal: Predict Vehicle Fuel Economy over Drive Cycles

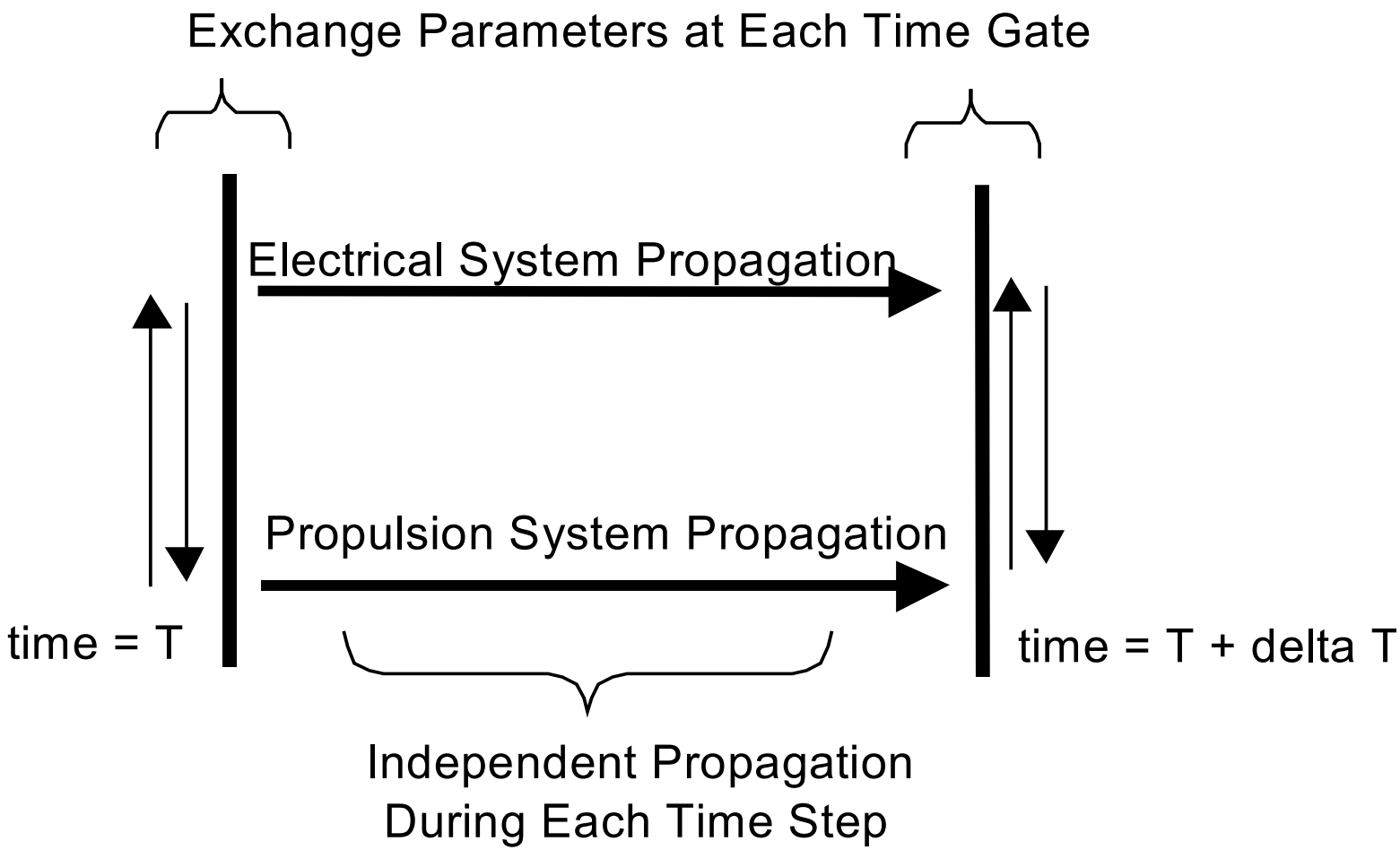
Electrical System Integration

- The electrical architecture has two main sections
  - The electrical charging, storage, and propulsion components
  - The traditional electrical loads on the vehicle

Co-Simulation Strategy

- Model the electrical components in Saber
- Model the mechanical vehicle components in ADVISOR
- Swap the necessary information between Saber and ADVISOR often
  - Drive torque required, generator torque required, etc.
- Solve with co-simulation

Theoretical Co-Simulation Concept



Comparison of Analysis Methods

Saber – ADVISOR Co-Simulation

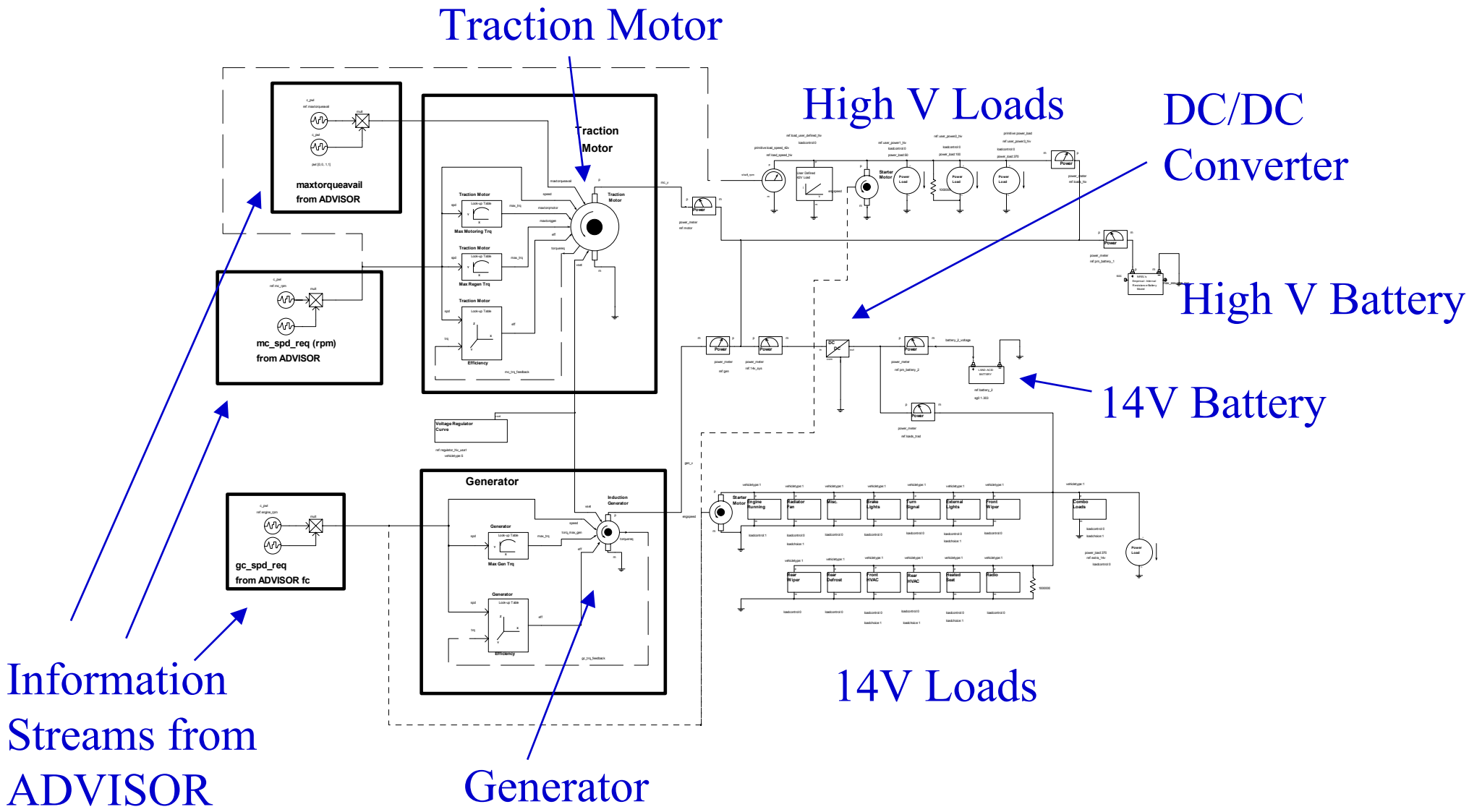
- Sets up actual circuit equations
- Solves circuit differential equations
- Component models can be as "electrical" versus empirical as one wishes
- Could have three phase machine circuitry if desired
- DISADVANTAGE – Requires Saber Software and license

Original ADVISOR

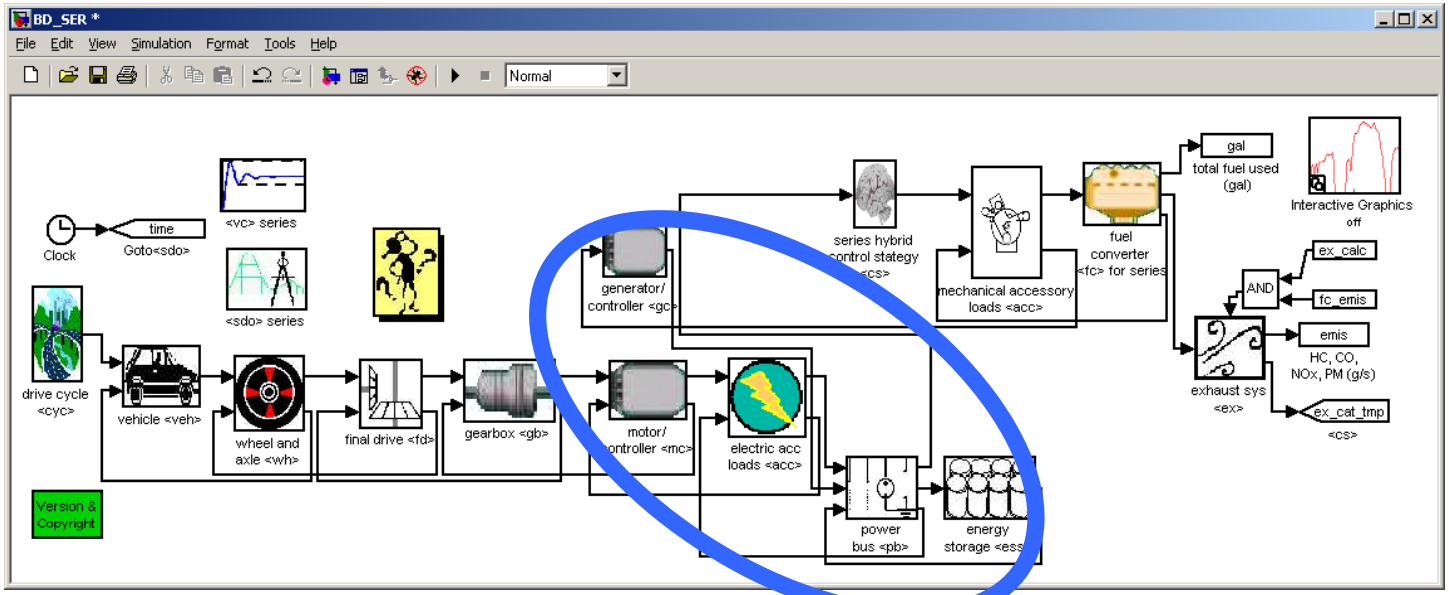
- Fast - Electrical solutions based upon power flow
- DISADVANTAGE – Does not represent the true physics and interaction of the electrical circuit components

Series Hybrid Electrical Architecture

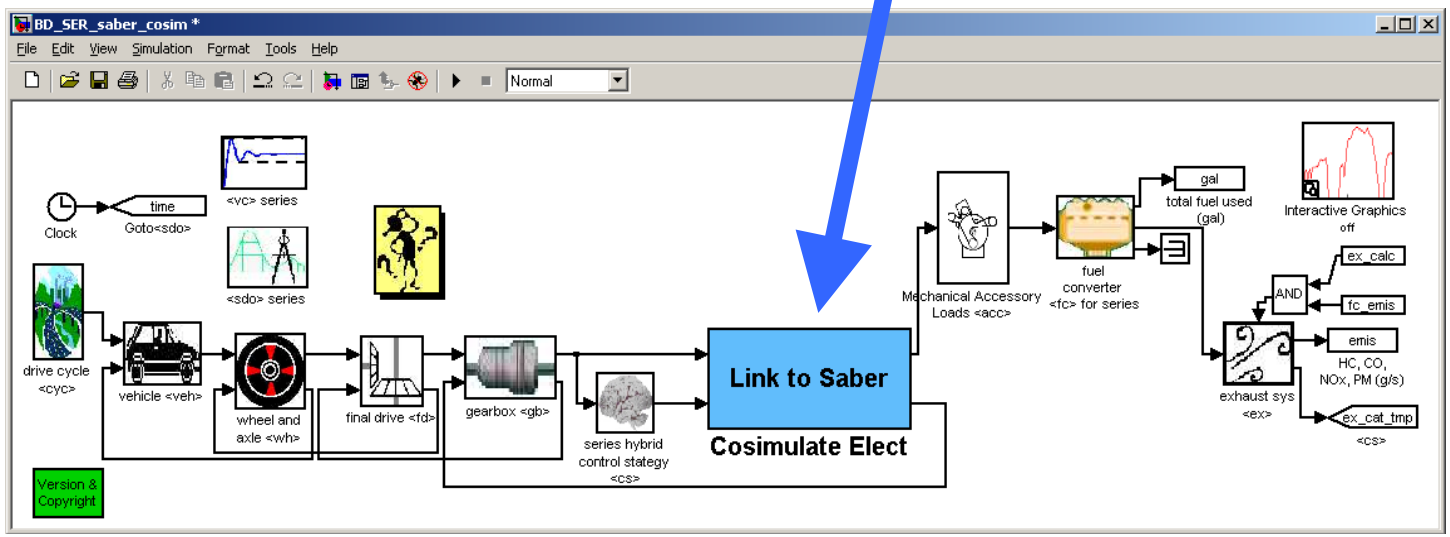
(Saber Sketch Electrical Schematic for Co-Simulation with ADVISOR)



ADVISOR Schematic Changes

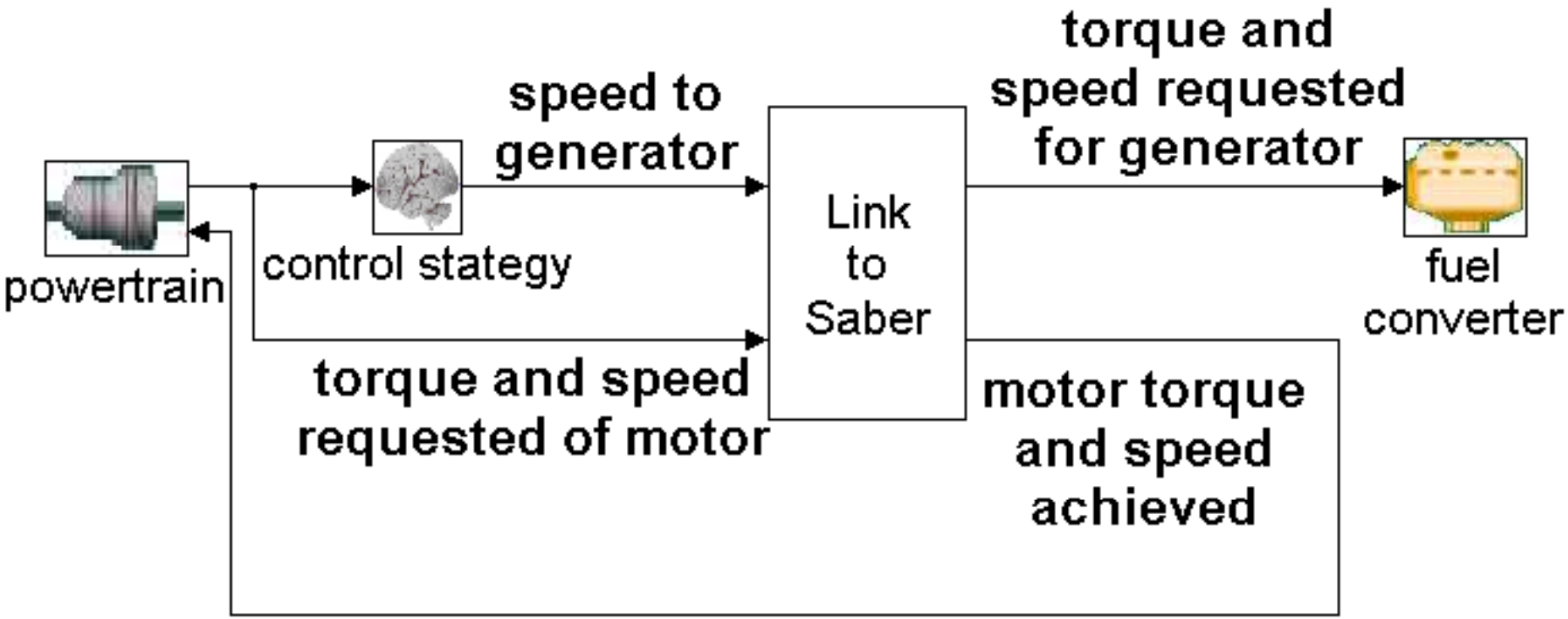


Traditional ADVISOR Without Co-Simulation

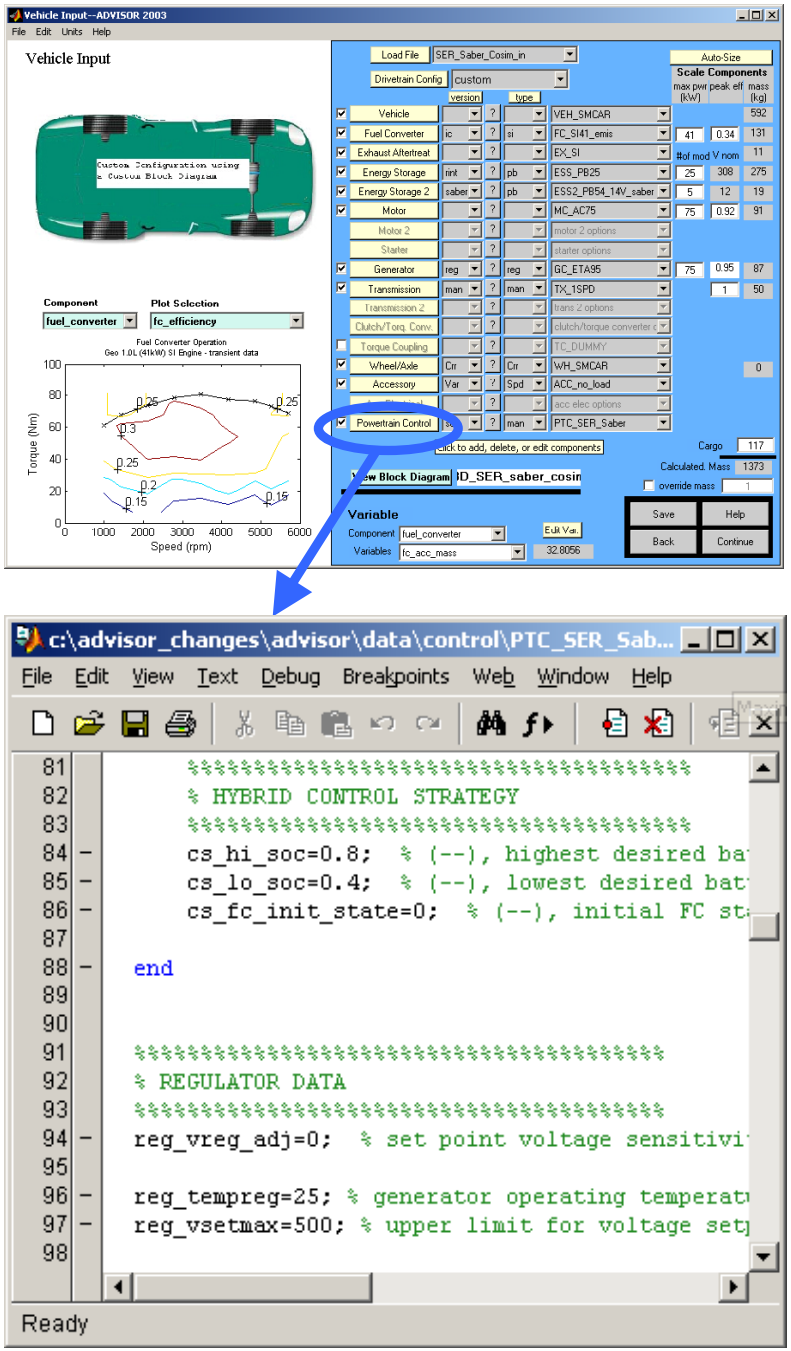


New ADVISOR With Co-Simulation

Signal Communication

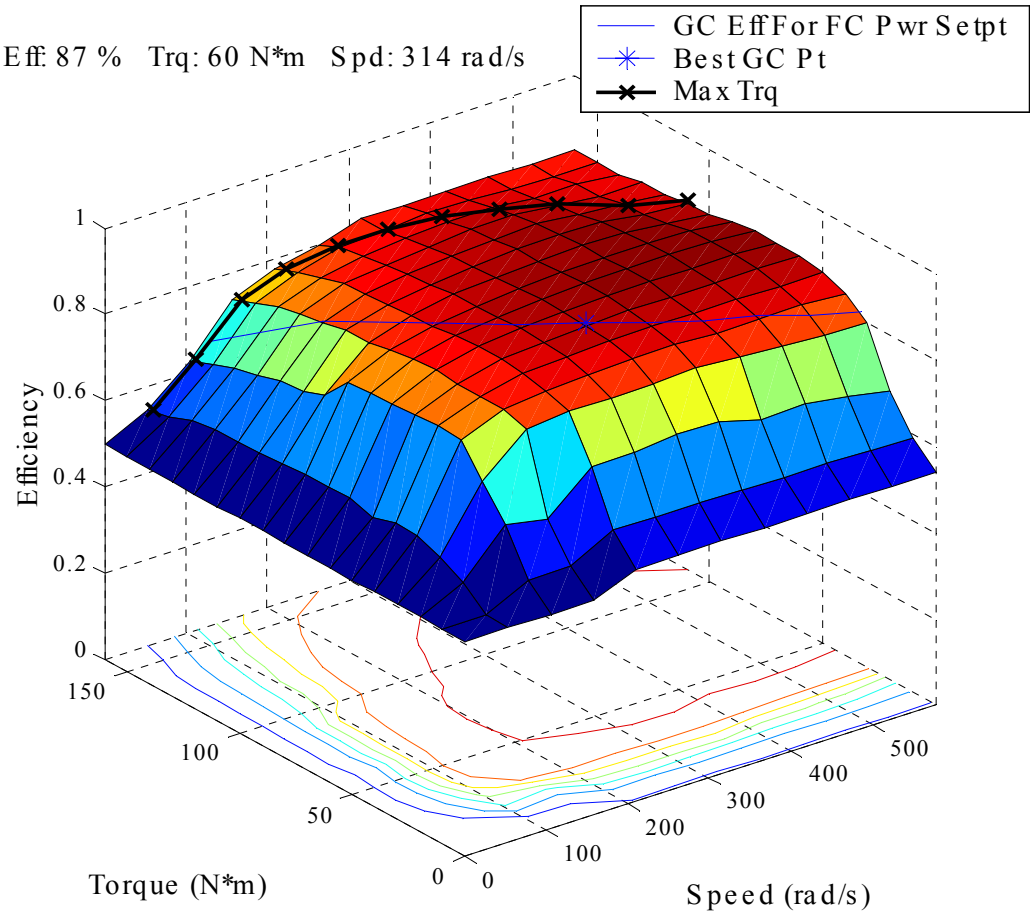


Controls



Utilizes control files as earlier versions of ADVISOR. Co-Simulation is fully Integrated.

Optimization of Pulley Ratio



1) Applies to series hybrids only

2) Determines optimal speeds for the engine and the generator.

3) Selects optimal pulley ratio so the engine can run at the optimal operating point and the generator can run at its optimal operating point.

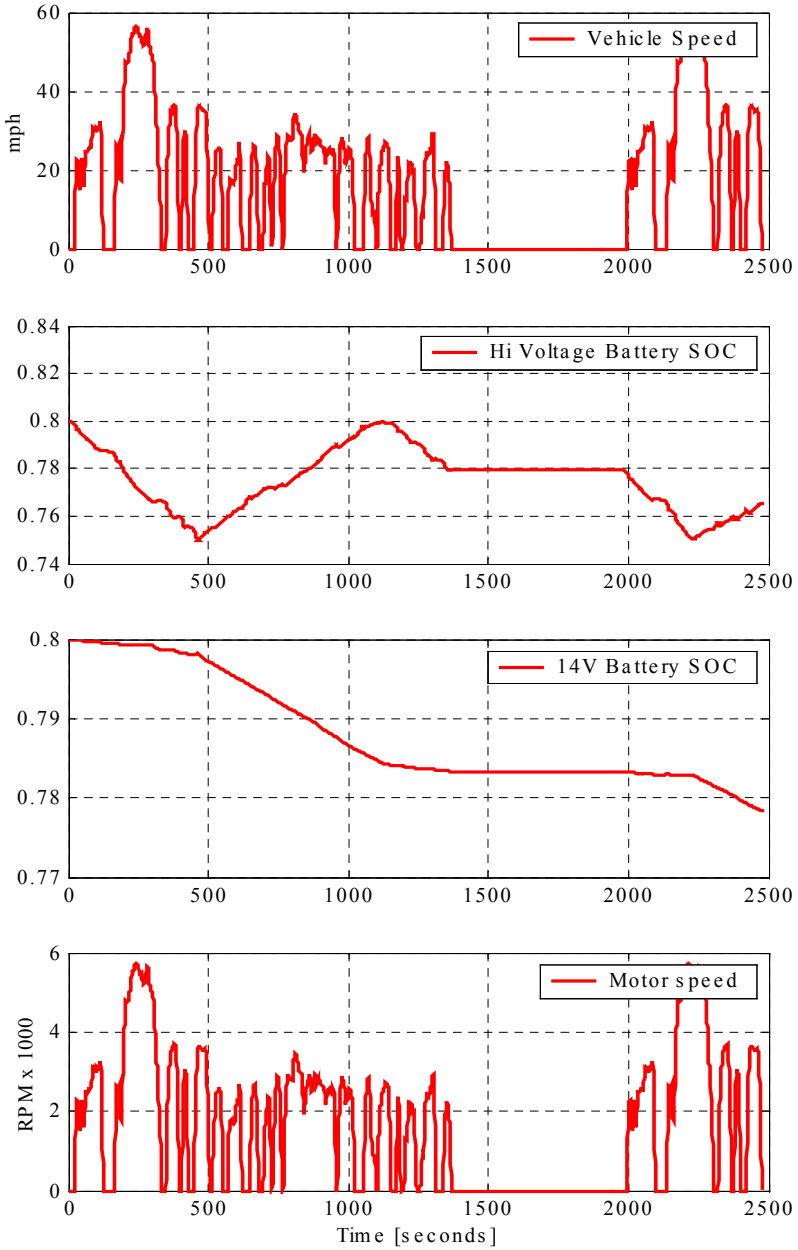
Vehicle Plots

Vehicle Speed – FTP 75 Cycle

High Voltage Battery SOC

14V Battery SOC

Motor Speed



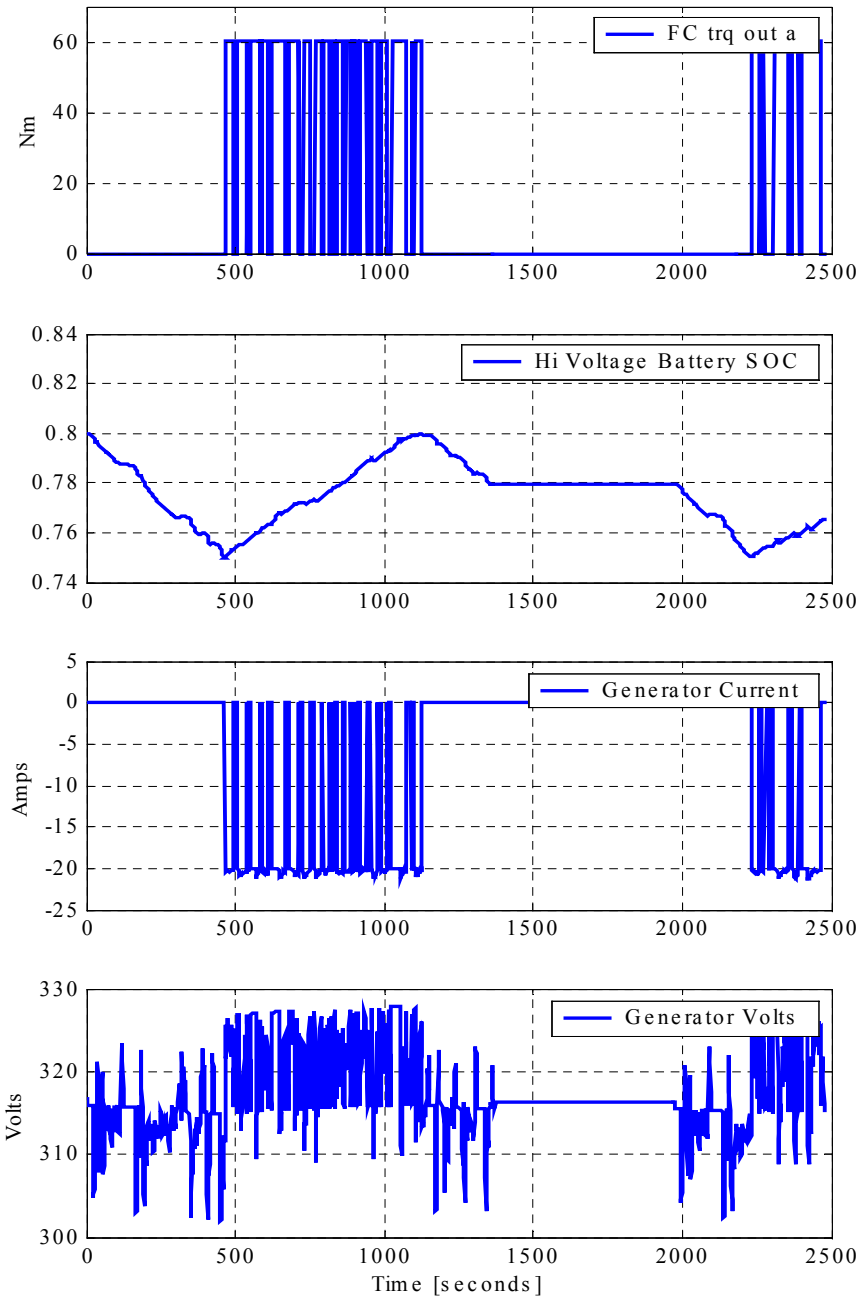
High Voltage Plots

Fuel Converter Torque Out

High Voltage Battery SOC

Generator Current

Generator Voltage



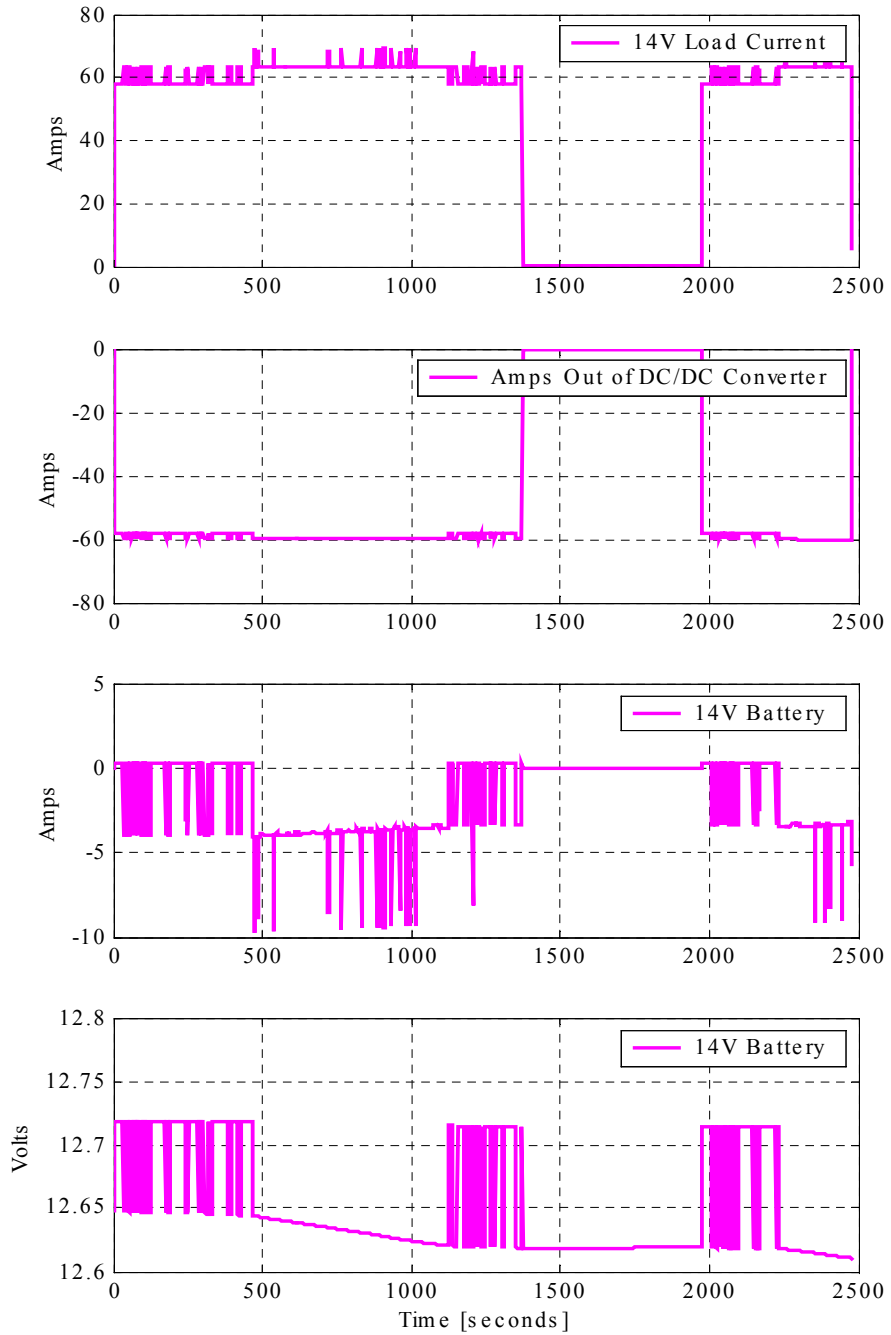
Low Voltage Plots

14V Load Current

Amps from DC/DC Converter

14V Battery Amps

14V Battery Voltage



Energy Balance Challenges

It is important to establish an energy balance

- A change in battery storage implies an error in gasoline utilization for propulsion

It is difficult to establish an energy balance with two batteries

Strategy 1 – balance the higher voltage battery since it tends to be the higher capacity battery.

Strategy 2 – disable the DC/DC converter and add an appropriate load to the high voltage bus

Conclusions

An improved series hybrid vehicle model now exists

The model takes advantage of appropriate simulation tools for the mechanical and electrical architectures of the vehicle

- The mechanical portions reside in ADVISOR in Simulink
- The electrical portions reside in Saber

The improvement is the refinement of the representation of the electrical architecture